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Acquisition and Spreadsheet Analysis of Real Time Dust Exposure Data: A Case Study

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Personal sampling with a light-scattering monitor connected to a data logger has been used to evaluate the effectiveness of a high-velocity, low-volume (HVLV) sander hood used in a plant manufacturing reinforced plastics. Exposures to sanding dust were determined for two workers, one using a sander with a hood, the other using a sander with none. Both workers were partners in a two-person team sanding a truck hood and fender assembly. Side-by-side filter sampling was conducted to calibrate the aerosol monitor. Data logger output for each worker was combined into a single spreadsheet program. Simultaneous video recording allowed worker activity variables (sanding, compressed air blowing, and other) to be coded onto the spreadsheet, which permitted calculation of the contribution of each activity to each worker's dose of dust. The computerized data acquisition system permitted identifying activities that change worker exposures through review of the work cycle while tracking worker exposures. Though not able (nor intended) to replace integrated sampling, the data acquisition system can be a good complement to traditional sampling methods. The computerized data acquisition system can save time since sampling can be performed and analyzed in as quickly as a few minutes using easily learned techniques. O'Brien, D.M.; Fischbach, T.J.; Cooper, T.C.; Todd, W.F.; Gressel, M.G.; Martinez, K.F.: Acquisition and Spreadsheet Analysis of Real Time Dust Exposure Data: A Case Study. *Appl. Ind. Hyg.* 4:238-243; 1989.

Introduction

Identifying exposure-causing work activities, evaluating the effect of process changes, and determining the performance of engineering control measures are formidable tasks. If little data exist, industrial hygienists and engineers may resort to trials to provide the data necessary to arrive at a decision. Real time instrumentation (monitors that continually analyze for contaminants), used with data and video recording equipment, can rapidly generate data to complement traditional sampling methodology in these trials.⁽¹⁻³⁾ This study concerns an application of these techniques to the evaluation of tool-mounted, high-velocity, low-volume (HVLV) exhaust hoods used on hand-held sanders. In this study, real time instrumentation was utilized to obtain a time history of exposure during a short (e.g., 20-minute) sampling period. A

stopwatch-equipped video camera was stationed to identify work activities. Exposure measurements of workers with and without hoods were combined with activity measurements on a spreadsheet to test the effect of the hood using regression analysis and to estimate potential exposure reductions.

Methodology

Each sander operator was studied using a hand-held aerosol monitor (HAM) connected to a data logger (Rustrak Ranger) and his/her activities videotaped. One instrument was used to sample a worker's dust exposure while using a hooded sander; a second was used for a worker using an uncontrolled sander. The HAM is a device that indirectly measures the quantity of airborne dust by determining the amount of light scattered by dust particles. The measured level is a function of the optical properties of the specific dust. The instrument is calibrated by comparing the instrument output signal, integrated over a given time period, to a measurement obtained by conventional (filter) techniques over the same time period. This determines the instrument's response or calibration factor. The average response factor for each instrument was within 10 percent of the other so that a single value of 5.4 mg/m³/volt was used for both instruments. It is important to note that this is an *average* calibration factor. No industrial source produces dusts of constant particle size distribution or optical properties. Therefore, actual instantaneous concentrations may differ from instrument output.

The HAM provides a 0-2 volt (DC) analog output voltage. This output was connected to the data logger and recorded. Data from the logger were replayed to a personal computer via application software (Pronto) for storage on floppy disc as a data logger file. This software allowed creation of a data base file that could be read by a spreadsheet program (Lotus 1-2-3). The video tapes were replayed, selected activities and their associated times were entered into the spreadsheet, and regression analysis performed.

Results

Real time exposure data were collected for two workers, one using the HVLV hood-equipped sander, the other using the uncontrolled tool. Since the work task is repetitive, one 20-minute segment was selected for analysis, the time required to sand two

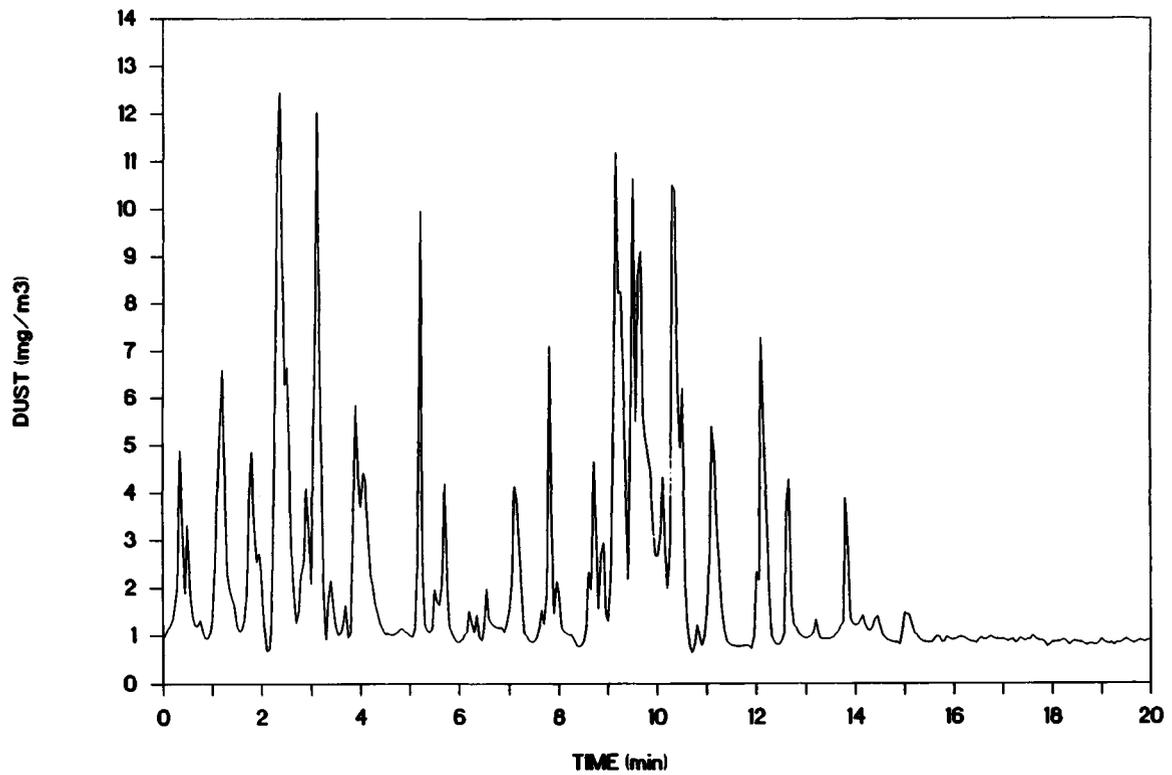


FIGURE 1. Real time data for worker using sander not equipped with HVLV hood.

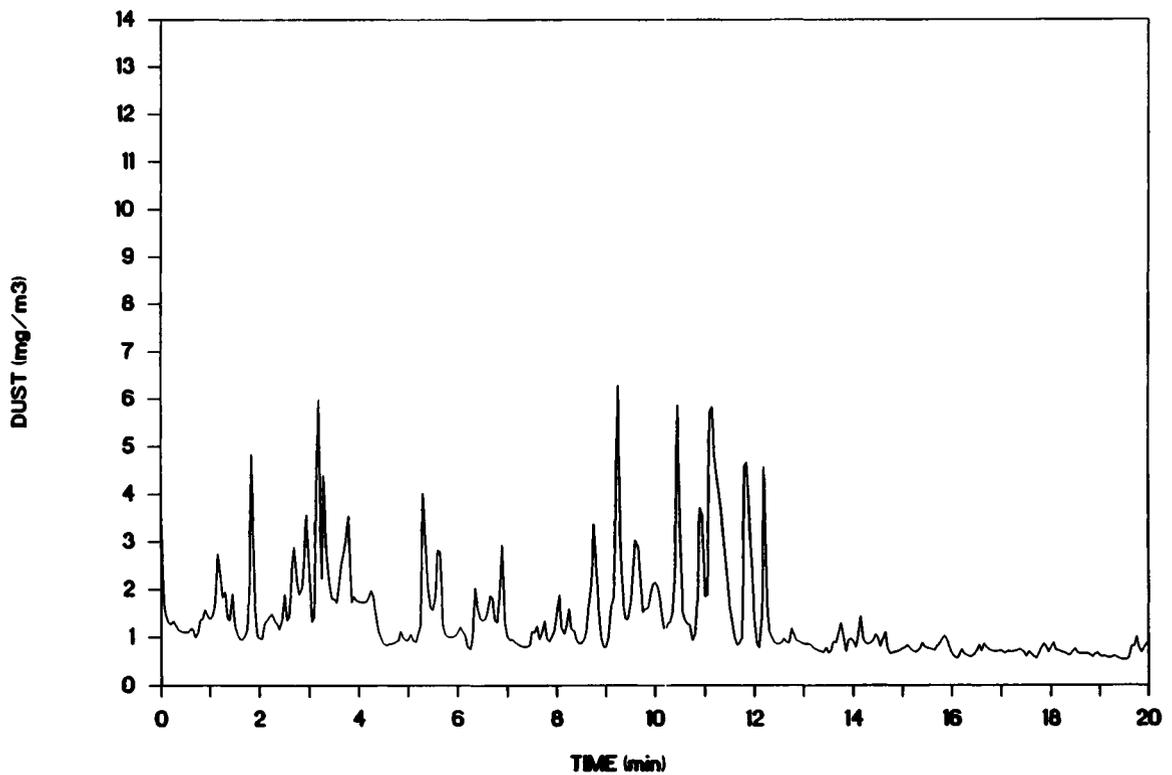


FIGURE 2. Real time data for worker using sander equipped with HVLV hood.

WORKER A NO HOOD, WORKER B HVLV HOOD

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R			
1	WORKER		WORKER	A:		B:		B:		A:		B:		B:		B:		B:			
2	SEC	A	B	DIFF	SAND	AIR	SAND	AIR	CONG-	PRE-	RESID-										
3		(mg/m ³)	(mg/m ³)		0-yes	0-no	0-yes	0-no	TANT	DICTED	UAL										
4																					
5	0	0.95	3.53	-2.58	1	0	1	0	1	0.20	-2.78										
6	3	1.04	1.76	-0.71	1	0	1	0	1	0.20	-0.91										
7	6	1.14	1.48	-0.34	1	0	1	0	1	0.20	-0.54										
8	9	1.21	1.32	-0.11	1	0	1	0	1	0.20	-0.31										
9	12	1.34	1.27	0.07	1	0	1	0	1	0.20	-0.13										
10	15	1.71	1.34	0.37	1	0	1	0	1	0.20	0.17										
11	18	2.04	1.27	0.77	0	0	1	0	1	2.45	-1.68										
12	21	4.90	1.17	3.73	0	0	1	0	1	2.45	1.28										
13	24	3.19	1.14	2.06	0	0	1	0	1	2.45	-0.39										
14	27	1.88	1.12	0.77	0	0	0	0	1	1.41	-0.64										
15	30	3.32	1.11	2.21	0	0	0	0	1	1.41	0.80										
16	33	1.88	1.12	0.76	0	0	0	0	1	1.41	-0.65										
17	36	1.42	1.18	0.24	0	0	0	0	1	1.41	-1.17										
18	39	1.22	1.18	0.04	0	0	0	0	1	1.41	-1.37										
19	42	1.19	1.00	0.20	0	0	0	0	1	1.41	-1.21										
20	45	1.33	1.10	0.23	0	0	0	0	1	1.41	-1.18										
21	48	1.12	1.37	-0.25	0	0	0	0	1	1.41	-1.66										
22	51	0.96	1.39	-0.43	0	0	0	0	1	1.41	-1.84										
23	54	0.94	1.59	-0.65	0	0	0	0	1	1.41	-2.06										
24	57	1.06	1.45	-0.39	0	0	0	0	1	1.41	-1.80										
25	60	1.31	1.38	-0.07	0	0	0	0	1	1.41	-1.48										
26	63	2.32	1.45	0.87	0	0	0	0	1	1.41	-0.54										
27	66	3.72	1.65	2.06	0	0	0	0	1	1.41	0.65										
28	69	5.32	2.75	2.57	0	0	0	0	1	1.41	1.16										
29	72	6.60	2.40	4.20	0	0	0	0	1	1.41	2.79										
30	75	4.59	1.83	2.75	0	0	0	0	1	1.41	1.34										
31	78	2.38	1.96	0.42	0	0	0	0	1	1.41	-0.99										
32	81	2.00	1.40	0.60	0	0	0	0	1	1.41	-0.81										
33	84	1.81	1.36	0.45	0	0	1	0	1	2.45	-2.00										
34	87	1.65	1.93	-0.28	1	0	1	0	1	0.20	-0.48										
35	90	1.20	1.26	-0.06	1	0	1	0	1	0.20	-0.25										
36																					
37																					
												Regression Output:									
												Constant	0.00								
												Std Err of Y Est	1.67								
												R Squared	0.17								
												No. of Observations	448								
												Degrees of Freedom	443								
												X Coefficient(s)	-2.25	-1.61	1.04	0.72	1.41				
												Std Err of Coef.	0.30	0.53	0.32	0.48	0.17				

FIGURE 3. Section of spreadsheet showing analysis of real time data.

hood assemblies. Real time air sampling plots are presented in Figures 1 and 2.

Data Analysis

The exposure data for each worker are contained in separate data logger files, containing essentially one data point for each 650 millisecond period. The application software (Pronto) allows for creation of compatible files for output to data base spreadsheets. Since all but the shortest of test runs would create an extraordinarily large spreadsheet, the software allows user selection of a time interval between spreadsheet entries. In addition, meaningful analysis requires independent measurements (the subject of autocorrelation will be discussed later). Since the response time of the measuring instrument was 1 second, a time interval of 3 seconds was selected as a first estimate. The elapsed time and 3-second average instrument output data for each worker were combined into a single Lotus 1-2-3 spreadsheet. A portion of this spreadsheet is shown in Figure 3. Concentration was calculated from the instrument voltage output by multiplying by a constant (the instrument response factor 5.4 mg/m³/volt, determined as described earlier). Video tapes were reviewed, and activity variables were assigned to each exposure datum. The activity variable "sanding" (columns E and G on the spreadsheet) was assigned the value "0" if the worker was sanding during the 3-second interval, "1" if he/she was not. The activity variable "blowing" (columns F and H) was assigned the value "1" if the worker was cleaning the hood assembly surface with compressed air during the 3-second interval, "0" if he/she was not (the choice of variable values will be discussed later). By looking at the changes in the worker dust exposures (columns B and C on the spreadsheet) the sampling lag/instrument response was estimated to be about 6 seconds. Thus, the instrument output column was offset by two rows to compensate for this delay. The difference in exposure between worker A and worker B was calculated in column D. Ideally, this difference would be caused by the presence of the hood on the sander used by worker B. To test this premise, an initial multiple regression analysis was performed using the difference in exposure between worker A and worker B as the dependent variable (the Y-range). The activity variables (columns E through H) were selected as the independent variables (the X-range). The regression routine in Lotus 1-2-3 calculates the coefficients and the intercept of the best fitting straight line. It indicates the statistical accuracy of the coefficients but not of the y-intercept. To force Lotus 1-2-3 into evaluating the errors associated with this intercept, the intercept is forced to be zero (a Lotus option) and a fifth coefficient calculated for the independent "variable" 1 (column I). The regression equation is of the following form:

$$\text{Exposure difference} = C1 \times A_s + C2 \times A_a + C3 \times B_s + C4 \times B_a + C5 \times 1$$

where:

- C1-C4 = coefficients of regression
- A_s = sanding activity of worker A
- A_a = compressed air activity of worker A
- B_s = sanding activity of worker B
- B_a = compressed air activity of worker B
- C5 = constant or intercept of regression line

When both workers are sanding, all the activity variables are 0; therefore, the exposure difference is equal to the constant. If this constant is significantly different from zero, then the hood can be said to produce a significant effect. In this case, by inspection

of the regression output "Std Err of Coef" corresponding to Coefficient 5, it can be seen that it is significantly different from zero at a level of confidence greater than 99.9 percent. The 95 percent confidence limit for the exposure difference between the two workers is 1.4 mg³ ± 0.3 mg³ (calculated by multiplying the "Std Err Coef" in Figure 3 by 1.96 and adding/subtracting the result to Coefficient 5).

Since real time data do not consist of simple sets of independent measurements, each data point may be some function of the preceding measurements. To determine the degree of dependence or autocorrelation, the regression equation was used to calculate a predicted exposure difference (column I on the spreadsheet). The predicted exposure difference minus the observed exposure difference was calculated in column K (the residual). If the real time data are independent, the residual values should be random numbers. To test for time dependence, the residuals were copied to an empty section of the spreadsheet. The residuals were recopied to adjoining columns but offset by one, two, and three readings corresponding to delays of 3, 6, and 9 seconds as shown in Figure 4. Regression analyses were performed on these residuals to determine autocorrelation. The data set demonstrated that each reading was dependent only on the reading immediately preceding it. The time dependence was removed from the original data set by eliminating every other data point, then performing a regression on the reduced, time independent data set. The intercept for this regression was still significantly different from zero.

Three regression analyses were performed: the first to determine if the difference in exposure between the two workers was statistically significant, that is, the hood was effective; the second to determine if the data was time independent (it was not); and the last to determine if the exposure difference between the two workers was statistically significant when the time dependence removed. Table I summarizes the steps used in this analysis.

Discussion

The above analysis demonstrated that the exposure difference between the two workers was statistically significant. That this difference was due to the presence of the hood can only be assumed, if it is accepted that both workers performed their tasks in the same fashion. Review of the videotapes did not reveal any overt differences in work practices. Unfortunately, plant conditions did not permit the experiment to be repeated with the

TABLE I. Summary of Steps in Data Collection and Analysis

- Collect data using data logger and stopwatch-equipped video camera.
- With data logger software:
 - Transfer data from logger to personal computer.
- Create a data base file.
- With spreadsheet:
 - Import data base files into a spreadsheet file.
 - Combine individual files into a single spreadsheet.
 - Convert voltage data into units of exposure.
 - Review video tapes and code worker activities.
 - Examine data for instrument delay and correct as necessary.
 - Calculate the exposure difference.
 - Perform a multiple regression to determine the significance.
 - Calculate the predicted difference and the residual.
 - Examine the residuals for time independence.
 - Create a time independent data set.
 - Determine if the difference is still significant.
 - Sort data and determine effects of activities.

workers' roles reversed (worker A using the hooded sander; worker B using the uncontrolled tool) to provide rigorous proof.

Sorting the data using the activity variables as the sorting criteria allows easy determination of the contribution of the various work activities: sanding, using compressed air, and other. Activities falling into the class "other" included waiting for hood assemblies, moving unfinished or finished products, and preparing repair compounds (body filler). The relative importance of each activity was ascertained by calculating the integrated concentration (concentration-time product). If the average dust concentration during "other" activities is subtracted from the average concentration during "sanding," then the contribution of that worker's own "sanding" activities can be measured and the results compared for the hood equipped and uncontrolled tools. The results of these calculations are presented in Table II. The hood resulted in an approximate two-thirds decrease in dust concentration due to sanding. Since the hood emission rate was not measured directly, the degree of reduction may have considerable uncertainty, as it represents the ratio of numbers of great variability. "Other" sources represent about one-half of the dust dose. Since none of the "other" activities involve dust-generating operations, this dose must be due to cross-contamination

from other workers sanding in the vicinity.

Blowing dust off the hood assembly did not appear to result in an appreciable dust dose to the two workers studied, "blowing" representing from 2 to 8 percent of the total dose. It can be seen from viewing the video tapes that visible clouds of dust are blown away from the workers. Thus, although the two workers took care not to blow dust at each other, their activities probably increased the exposure of others. Use of the compressed air nozzles not only removed dust from the hood assembly but also re-entrained dust that had settled to the floor.

Conclusions and Recommendations

A computerized data acquisition system, utilizing real time instrumentation and a video taping system, can provide the information necessary to identify the activities that most affect worker exposure levels. A minimum data acquisition system would require a real time instrument with an analog output, a video camera and recorder capable of displaying time of day (seconds), a data logger with input adaptable to the instrument output, an IBM-compatible computer equipped with two disc drives, and both data logging and spreadsheet software.

CHECK FOR AUTOCORRELATION

	A	B	C	D	E	F	G	H	I
	0 sec	+3 sec	+6 sec	+9 sec					
1									
2									
3	-2.78	-0.91	-0.54	-0.31		0 vs 3			
4	-0.91	-0.54	-0.31	-0.13		Constant			-0.00
5	-0.54	-0.31	-0.13	0.17		Std Err of Y Est			1.39
6	-0.31	-0.13	0.17	-1.68		R Squared			0.30
7	-0.13	0.17	-1.68	1.28		No. of Observations			445
8	0.17	-1.68	1.28	-0.39		Degrees of Freedom			443
9	-1.68	1.28	-0.39	-0.64					
10	1.28	-0.39	-0.64	0.80		X Coefficient(s)		0.55	
11	-0.39	-0.64	0.80	-0.65		Std Err of Coef.		0.04	
12	-0.64	0.80	-0.65	-1.17					
13	0.80	-0.65	-1.17	-1.37					
14	-0.65	-1.17	-1.37	-1.21		0 vs 6			
15	-1.17	-1.37	-1.21	-1.18		Constant			-0.00
16	-1.37	-1.21	-1.18	-1.66		Std Err of Y Est			1.65
17	-1.21	-1.18	-1.66	-1.84		R Squared			0.02
18	-1.18	-1.66	-1.84	-2.06		No. of Observations			445
19	-1.66	-1.84	-2.06	-1.80		Degrees of Freedom			443
20	-1.84	-2.06	-1.80	-1.48					
21	-2.06	-1.80	-1.48	-0.54		X Coefficient(s)		0.15	
22	-1.80	-1.48	-0.54	0.65		Std Err of Coef.		0.05	
23	-1.48	-0.54	0.65	1.16					
24	-0.54	0.65	1.16	2.79					
25	0.65	1.16	2.79	1.34		0 vs 9			
26	1.16	2.79	1.34	-0.99		Constant			-0.00
27	2.79	1.34	-0.99	-0.81		Std Err of Y Est			1.66
28	1.34	-0.99	-0.81	-2.00		R Squared			0.00
29	-0.99	-0.81	-2.00	-0.48		No. of Observations			445
30	-0.81	-2.00	-0.48	-0.25		Degrees of Freedom			443
31	-2.00	-0.48	-0.25	-0.18					
32	-0.48	-0.25	-0.18	-0.04		X Coefficient(s)		0.07	
33	-0.25	-0.18	-0.04	-2.09		Std Err of Coef.		0.05	
34	-0.18	-0.04	-2.09	-0.57					
35	-0.04	-2.09	-0.57	1.44					
36	-2.09	-0.57	1.44	1.28					
37	-0.57	1.44	1.28	-2.87					
38	1.44	1.28	-2.87	-0.57					
39	1.28	-2.87	-0.57	0.29					
40	-2.87	-0.57	0.29	-0.12					
41	-0.57	0.29	-0.12	-1.18					
42					
43					

FIGURE 4. Section of spreadsheet showing determination of autocorrelation.

TABLE II. Analysis of Real Time Sampling Data for the Sanding Operators. (Numbers in table are based on sorted data from reduced [time independent] data set.)

Activity	Uncontrolled Sander				Hooded Sander			
	Time (sec)	Dose (mg/m ³ -s)	%	Conc. (mg/m ³)	Time (sec)	Dose mg/m ³ -s	%	Conc. (mg/m ³)
Sanding	381	1410	54	3.7 (3.1)*	306	551	31	1.8 (0.9)
Blowing	48	58	2	1.2 (1.0)	60	138	8	2.3 (0.7)
Other	912	1157	44	1.3 (1.0)	975	1073	61	1.1 (0.9)
Total	1341	2625	100		1341	1762	100	
Avg. Sanding Concentration:				3.7				1.8
Avg. Concentration During "Other" Activities:				1.3				1.1 (0.9)
Avg. Difference:				2.4				0.7
Estimated Percent Reduction (due to hood):								71%

*Values in parentheses indicate standard deviation.

The use of data acquisition system in this study shows that the system is very flexible and provides more detailed information than traditional integrated sampling alone. Although not able (nor intended) to replace integrated sampling, the data acquisition system can be a good complement to traditional sampling methods. Whereas integrated sampling can determine if the working environment is acceptable, real time monitoring can provide temporal details that can be useful in identifying job aspects which are sources of exposure. In addition, the computerized data acquisition system can save time since sampling can be performed and analyzed in as quickly as a few minutes.

References

1. Gressel, M.G.; Heitbrink, W.A.; McGlothlin, J.D.: Advantages of Real-Time Data Acquisition for Exposure Assessment. *Appl. Ind. Hyg.* 3:316 (1988).
2. Heitbrink, W.A.; O'Brien, D.M.; Gressel, M.G.; McGlothlin, J.D.: Practical Application of Aerosol Instrumentation to Occupational Dust Control Problems. In: *Proceedings of the Technical Program: Power and Bulk Solids Handling and Processing*, May 12-14, 1987, Rosemont, IL.
3. Cecala, A.B.; McClelland, J.J.; Jankowski, R.A.: Substantial Time Savings Achieved Through Computer Dust Analysis. *Appl. Ind. Hyg.* 3:203 (1988).

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